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A STRUCTURAL STUDY OF THE CATERPILLARS: III, THE SOMATIC MUSCLES.

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In consideration of the very few dissections of the muscular system of Lepidoptera which have been published, and their radically different interpretation, it has seemed advisable to study a few more forms and trace if possible the points of disagreement.

PREPARATION.

A serious matter in such a research is the preparation of material. The muscles are small and slender, quite difficult to trace without a good microscope and plenty of light, easily broken in dissection in hardened material, and almost perfectly transparent when fresh. Besides this they do not differ in color from the fat with which they are intermingled, and when preserved in formalin hardly differ in consistency. The most satisfactory material was opened out after killing with cyanide, and pinned out on a piece of cork; then treated with strong corrosive sublimate (bichloride of mercury) and dissected while immersed in a dilute solution of the sublimate. This makes the muscles intensely white, distinguishable from the fat by their silky luster; but the mercury attacks dissecting instruments badly and so most of the work was done with material preserved in formalin (4 per cent., that is, 10 per cent. of the commercial solution). Alcohol was also tried, and was nearly as good; the muscles being darkened

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a good deal in some cases, which made them more difficult to see in a dim light, but brought them out in contrast with the fat. For the work with the thorax it is important to open up the caterpillar and pin it out before hardening, as otherwise many of the muscles will be broken. If specimens are to be preserved whole for dissection purposes they should be killed in hot water, or injected with a stronger solution of preservative to prevent decay. The prothorax and last segment are particularly hard to get in a satisfactory condition, because of their peculiar shape, and the close connection of the former to the head, which should be split vertically when opening the caterpillar. It is most convenient to open the caterpillar near, but not quite on the middorsal line.

The viscera and loose fat of the body cavity are removed as a preliminary, as well as the wings of the heart, leaving the heart, trunk trachea and nervous system as long as possible for landmarks. The dissection can follow the order given by Lyonet, to advantage, but it is often unnecessary to open any specimens by the venter, as the dorsal musculature is comparatively simple, and is often uninjured on one side. Plate XIX follows this order fairly closely in its six stages, but in other plates less stages are shown for economy.

It soon appeared that the muscles represented by Lyonet, for the Goat moth caterpillar, could be found in such widely divergent forms as a Sphinx, a Noctuid and a Lasiocampid, so his lettering is used in the figures. Lubbock's dissection was hardly as perfect, while Berlese's figures are wholly diagrammatic and useless for the study of homologies; in fact several of his comparisons with the muscles of other insects are invalid. We will only be able to come to a true knowledge of the homologies when the nerve-muscle relations are fully worked out; and in the Lepidoptera the matter is much confused by the anastomoses between all three pairs of nerves, and even between successive segments.

THORAX.

To go on to details; I have not made any satisfactory dissection of the *prothorax*. Evidently however, Lyonet represents the state of affairs much more accurately than Berlese. The dissection figured on Plates 1 and 2 may be taken as accurate so far as it goes, but is incomplete. The following comparisons may be made between Lyonet's, Lubbock's and Berlese's lettering:

LYONET.	LUBBOCK.	BERLESE.
C^+	82	CXXXIXa
D, E	1, 4, 5	139–140
A	6, 7	140b
α	22	CXXXIX
G, H, I, L	61, 62	CXXXIV
β, γ, δ, etc.	35, 76, 80, 81	CXLI
a, b	16, 17, 21	CXXXII
ζ	19, 20, 26	CXXXIIa
c	18.	CXXXIIb
r, etc.	77	129
i, l, etc.	70, 71, etc.	147
u, v	57, 58	XL

The whole arrangement is complex and only in a general way comparable to that of the other segments. C^+ is interesting as extending well beyond the segment line, and in Cossus the length of two whole segments—being the longest muscle in the caterpillar. It also crosses the middle line in Cossus, but not in Noctua, where it is shorter. If Lyonet is correct there are no longitudinal muscles within the nerves, (except perhaps the aberrant A and C^+ which presumably represent the great longitudinal muscles of the following segments); and some of the muscles are innervated from the subœsophageal ganglion, evidently belonging to the cervical system. The spiracle is supplied by the "bride epiniere" or so called sympathetic fibre, derived from the same segment, but it runs largely in the following one and seem to supply also some of its muscles, besides anastomosing with its first nerve. This indicates strongly that the spiracle originally lay on the incisure, as the rudimentary second one actually does, and that it has moved forward. For the same reason we see that the other spiracles have moved back, being supplied by the nerve of the preceding segment; and all the spiracles are accounted for.

The *meso-* and *metathorax* are perfect counterparts of each other, and strongly contrasted with the other segments in structure. The few points of difference between them noted by Lyonet, are further reduced by the correction of a couple of misinterpretations, and particularly by treating the three bellies of his α as separate muscles. In discussing these, and the remaining segments we may use Berlese's division of the segments into four annulets, illustrated on Plate IX, Figs. 1 and 2. These are the acro-, pro-, meso- and meta-tergites and sternites, separated by the antecosta, precosta and inter-costa. The tergopleural suture is indicated only by the position of the rudimentary wing, while the pleurosternal one is the strongly marked subventral fold, to which several muscles are attached. In the abdomen these boundaries are less distinct, but the pleurosternal suture can be traced in a general way, and the tergopleural must be placed at least a little higher, as indicated by the spiracle, which should lie within the pleuron. Of the true legs we have a well marked coxa, which is mostly membranous in the Sphinx, a strong femur, to which only one or two small somatic muscles are attached, and the rudiment of a trochanter, which bears the insertion of r. The insertion of the various muscles of the leg is beautifully shown by Lyonet, in Plate VIII, Fig. 7. In Cossus where the coxa is wholly chitinized k, n, p, s, t, u, v, x, ϵ, ϑ, κ, λ, μ, ν and ξ run to it. The body muscles may be divided as to their origin in the embryo into the dorsal and ventral longitudinal systems, and the lateral and ventral transverse ones; the last is not represented in the caterpillar by a developed muscle, but its rudiment may exist associated with the fork of the sympathetic nerve and the ventral diaphragm. This would be 4 of Berlese. The lateral transverse muscles are again divided into two sets, between which lies couple of longitudinal fibres (E of the abdomen) and the trunk trachea, but as the trunk trachea is not well developed in the thorax, and replaced by collaterals in the body cavity, the muscles must there be treated as a single unit. If we consider C, E and G as homologues of E, etc., of the abdomen θ will be the only fibre of the deep set in the thorax, as it is in the abdomen. It should be noted that the spiracles can migrate without disturbing these fibres, while the deep transverse fibres would have to be swept before them. The muscles also differ from each other in their normal or oblique direction, their length and their insertion. The table annexed classifies them, and gives the relations between meso- and metathorax, and between the various nomenclatures, omitting those muscles which puzzle me.

	LYONET		LUBBOCK	BERLESE	
	Meso-.	Meta-.		Meso-.	Meta-.
LONGITUDINAL DORSAL.					
Rectus (1)	A	A	1	70	37
	B	B	1	70	37
Oblique segmental	C	C	8	70b	37b
	E	E	8′		37c
	D	D	5	70a	37a
	F	F	5	70a	37a
	G, H	H	4		
	α (1st belly)	G	6, 7		
Shorter segmental	I	I			
To intercosta	K	K	61		
From precosta	L, M,	L,	9-11		
To precosta	S	S	62		
	T	T	63		
From intercosta	Q	Q	12, 13		
	R	R	14, 15		
To antecosta	λ (part)	λ (part)	64, 65 (part)		
INTRANEURAL (2)	c	c	18	+	
LONGITUDINAL VENTRAL, SUPRANEURAL					
Segmental	a	a	21	LXXII	XXX
	b	b	17	"	"
	–	d	(16)	"	"
	e, f	e	22	+	
	d	f	20	LXXII	XXX
	g	g	16 (19)	"	"
	h	h	23	"	"
To mid-ventral line behind coxæ	l	l	26	+	
LONGITUDINAL VENTRAL, SUBNEURAL					
To mid-line in front of coxæ	i	i		IVb (3)	
Crossed to front of coxa	k	k	24	IVa (3)	
Short anterior transverse (4)	z	z	25	+ (3)	
From mesosternite at mid-ventral line	n	n	28	+	
From precosta	m	α (3rd belly)	77		
Short fibres from leg	q	q	79		
	u	u	57	}V = Iα	
	v	v	58		
TRANSVERSE; TO PLEUROSTERNAL LINE					
Antecosta to prosternite	β	β	49		
Precosta to precosta, superficial	δ	δ	49		
Precosta to prosternite, deep	ν	ν			
Precosta to mesosternite	μ	μ	72	XVIIIa (3)	
Antecosta to posterior incisure	ϵ	γ	66	XXXIVa	
Antecosta to mesosternite	λ	λ	{70	XVII (3)	
	(posterior bellies)		65 (part)		
Intercosta to mesosternite	κ, ξ	κ, ξ	50	XVIIIa (3)	
Anterior incisure to precosta	γ	α (2d belly)	76		
To anterior incisure	η	η	40		XXXVIb
	w	w	41, 42		

	LYONET		LUBBOCK	BERLESE	
	Meso-.	Meta-.		Meso-.	Meta-.
ACROSS PLEUROSTERNAL LINE					
Intercostal region to leg	ζ, ϑ	ϵ, ζ, ϑ	46, 51	5α (3)	5
Posterior incisure to leg	t	t	55	XVIIβ (3)	
Superficial on incisure	θ	θ	35	XXXVI	XVIIa
Deep on incisure	x	x	34, 38	XXXVIa	XVIIIa
BELOW PLEUROSTERNAL LINE					
To leg	s	s	78	IIα, 6a	
To near midventral line	p	p	73-75		
SPIRACULAR (rudiment)	π				

NOTES: (1) *Muscles droits* of Lyonet.
(2) Passing between the two longitudinal connectives.
(3) Fig. 478.
(4) Certainly derived from longitudinal muscles like k. In the mesothorax it tends to cross the middle line.
+ Indicates that the muscle is represented but not named.

The wing is shown in the deepest layer of the dissection on Plate XVIII, in its normal position. The only fibres closely associated with it seem to belong to w and λ, practically all the pleural muscles being inserted far above it. Evidently the pleurites are very slightly developed in the caterpillar stage.

The *mesothorax* seems to differ from the metathorax as figured only in having a fibre or two more or less in the case of such homologous muscles as a, b, (d); β; Q. R. S and T. The union between thorax and abdomen is made with only a single disturbance of the musculature, aside from the fact that the ante- and precosta of the first segment of the abdomen are undeveloped; and that is that one head each of E and F have moved forward a short distance beyond the incisure, carrying with them a couple of fibres of θ, and attaching themselves to the insertions of G and t respectively.

MIDDLE SEGMENTS OF ABDOMEN.

One of the middle segments may be taken as typical of the abdomen. Examples of three families are figured on Plates XX, XXI and XXII. As compared with the thorax the most striking difference is the weak development of the oblique lateral muscles, and the absence of muscles that cross the median line; both conditions correlated with the simpler movements of this part of the body. Here also there are no such confusing cases as α of the thorax, where several morphologically widely separated muscles form a single functional unit. There is no fibre piercing the nervous system, and no short dorsal anterior muscles, though it was probably such a muscle ventrally, that gave rise to p′, which is wholly independent of p and x, though not well marked in Cossus and Malacosoma. In the abdomen the principal nerve divides the ventral muscles quite centrally, forming the most satisfactory distinguishing character between the fibres f and g, and forming the most fundamental distinction between a and the other recti; the relation of the dorsal muscles is more obscure, as the nerve divides up, but A, B and C evidently lie above, and E, F and H below it. The transverse muscles are divided into two groups as already noted in the case of the thorax. The following classification of the muscles gives their designation by Lyonet, Lubbock and Berlese.

	LYONET	LUBBOCK	BERLESE
LONGITUDINAL DORSAL			
Rectus	A	1	VII
	B	3	"
	C	2	"
Segmental	D	4	"
	G	5	"
From antecosta, oblique	F(4)	8	X
	H	7	"
From antecosta to antecosta	E	6	IX
From precosta	I	9	XI
	L	10, 11	"
From intercosta	Q, R	12, 15	XVI
LONGITUDINAL VENTRAL, SUPRANEURAL.			
Rectus	c	18	2
	b	17	"
	d(3)	16	"
Antecostal, oblique	f′ (in Malacosoma only)		
Longitudinal segmental	e	20	2
	ff	19	"
To antecosta of following segment	f	25	IV
From antecosta, oblique	h	+	
LONGITUDINAL VENTRAL, SUBNEURAL.			
Antecosta to antecosta, longitudinal	a	21	III
	i	22	"
To antecosta of following segment, oblique	g	24	IV
Segmental, oblique	g′	25	2
From front of leg	k	27	1 aα
From near midventral line, between legs	p	28-30	1a
From posterior side of leg	t	57	V
From leg toward mid-ventral line	x	56, 58	1aβ (1)
From near mid-ventral line to leg	(p′)	46(part)	1aβ
SPIRACULAR	M	45	
TRANSVERSE SUPRATRACHEAL.			
Acrosternal	θ	35	XVII
At precosta	θ(2)	36	"

	LYONET	LUBBOCK	BERLESE
TRANSVERSE SUBTRACHEAL, *Above subventral fold.*			
From near incisure to precosta	α	37, 38	XVIII
Mesotergite to mesosternite	δ, ϵ	51, 52	XVIIIa
Crossing the pleurosternal line.			
Spiracle to precosta	1	39	5b
Propleurite to precosta	m(sometimes)	42	5b
	q(rarely)	40, 41	
Mesotergite to parts of leg	β, γ	46–50	5α, 5β
Short posterior muscles	ζ, y	33–34	XVIII
Below the pleurosternal line.			
Behind precosta	q, m	40,41(42)	5bα
Across leg in front	n	43	6α
Across leg behind (from ψ)	r	53–54	6β
From fold or ψ to leg	γ(part)		6aα
From fold or ψ to anterior edge of following segment	ζ(part)	31–32	
	z	55	XVIIIβ?

NOTES: (1) 1aβ in most forms, not distinct from V in *Cossus*, I on legless segments
(2) The fibre of θ which runs between the precostae is marked 4 on the plates; it is not well defined in *Cossus or Sphecodina*. Fibres of θ proper spread fan-like from the acrosternite to various points in the acro- and protergites.
(3) To antecosta of following segment in *Phæocyma*.
(4) From acrosternite in *Phæocyma*.

The muscles which attach to the ends of the segments are sharply divided into two groups, in the first, comprised of A, B, C, E, a, b, c, d, the muscles of successive segments are united, forming a single polygastric muscle, the remainder are so inserted to leave a distinct space between muscles of successive segments. In the case of D and i, the distinction is striking, as compared with A and a respectively.

NERVES.

There are three pair of nerves from each abdominal ganglion. The principal or anterior one runs almost directly out from the anterior half of the ganglion, passing over all the muscles near the midventral line, but soon plunging in (between a and c) and running between the layers up to the subdorsal region, where it ends in a longitudinal fibre, perhaps the chordotonal organ. It supplies but little of the skin, but sends off numerous branches to the muscles, especially the larger segmental ones. The second or posterior pair of nerves runs obliquely downward under i, passes between k and p, often forming the only distinction between these two muscles, and then ramifies in the crowd of short muscles connected with the proleg, and on the skin. The third runs directly back as a single nerve from the posterior end of the ganglion under the fused connectives, until they separate, then forks, in the substance of the very slightly developed ventral diaphragm and runs out, often along the incisure, to the spiracle and from there to the tip of the wing of the heart; no muscles overlie its main stem, but it sends down branches to anastomose with the second nerve, and connects with the anterior one in the neighborhood of the spiracle. It certainly supplies the spiracle and probably some muscles, but on account of the anastomoses it is impossible to be sure. Sometimes the fusion of the connectives is complete, as in Sphecodina (Plate 5) and this nerve seems to arise from the anterior end of the ganglion after the one to which it belongs. In the thorax its connections are always perfectly clear, because of the wide separation of the connectives.

On the third to sixth segments the structure is identical, as described, except for purely individual variation, but the others show various stages of reduction.

OTHER SEGMENTS OF THE ABDOMEN.

The *second segment* differs only in the reduction of the muscles of the proleg, and the loss of a couple of fibres, but they do not change their points of insertion. x is insignificant or absent; k and p are usually unchanged, but may appear as short parallel oblique fibres evidently homologous to I and L dorsally. This condition appeared in an odd specimen of Malacosoma disstria. γ, m, n, q and r are reduced in strength, but not notably changed in points of insertion.

In the *first segment* the proleg is so reduced as to be unrecognizeable, in a stage corresponding to Berlese's Fig. 477 D, which was evidently prepared from the seventh segment. The fat pad, which causes the proleg of the second segment to keep nearly its normal relations, is unimportant here, and the transverse fibres (of the l, q group) are shortened. β, (representing γ) is merely a couple of fine fibres which barely cross the fold. The antecosta dorsally and precosta ventrally are also not developed and the muscles which normally end in them are continued to the front of the segment; these are a, i, E and f′ when present. As the trunk trachea disappears at the first spiracle α is not distinguished from θ, whose fibres are crossed as a result of the moving forward of E and F. H, however, may remain unchanged, and the spiracle is only a little in front of its usual position. The innermost fibres of c nearly meet in the middle line, covering the origin of a.

Toward the posterior end reduction is progressive to the last segment, and becomes extreme in the ninth, which however, is unmistakably a true segment. The fibres gradually go over to the rectus type, becoming simple and longitudinal, and gradually decrease in number, till in the ninth segment only five ventral ones are left.

The ganglia are fused in the *seventh segment* more or less completely, but always the true seventh ganglion is recognizable with its usual nerves,—,the sympathetic nerves from the last spiracle run back united with the nerve for the eighth, as far as the incisure, then run normally to the spiracle and last wings of the heart. All the principal muscles are present, but a, f, g, h, i and E do not extend beyond the eighth acrosternite, because of the disappearance of the pre and ante-costa of the eighth segment. The deep muscles are reduced, p and x appear clearly as longitudinal (oblique) muscles similar in character to I, L and Q, R of the dorsal region. ζ also appears longitudinal, a suggestive fact, as in general it resembles more closely the fanlike transverse muscles, but z is evidently transverse. α is normal, m and q are undifferentiated, and clearly pleurosternal; d is normal, n and r extraordinarily shortened, while β (representing γ) and δ are also nearly simple—evidently the proleg is merely the small area enclosed by n and r.

The *eighth segment* has the two normal nerves running back from its ganglion in the preceding segment. The first runs outside c, which apparently represents part of a of other segments; it passes between f and g, defining them as usual. Muscles a to i and the corresponding dorsal ones are all reduced to the simple segmental type, M and l, being connected with the spiracle, remain normal, but θ is simplified in front and its homologue behind is much reduced. The lateral muscles are perfectly simple, and the longitudinal ventral ones are reduced to a single set of sort fibres (p).

In the *ninth segment* with the disappearance of heart and spiracle the sympathetic is also gone, but the two principal nerves are easily found, (sometimes with the first arising behind the second). The first runs between a and b, which latter has to serve for b, c, d, e, f, ff, and h of normal segments;

e probably represents normal g, while d would be a transverse fibre. The odd fibre e' may be the last trace of the proleg. The posterior nerve, with the disappearance of the proleg, runs mainly to the skin.

The *last segment* is specialized to such an extent that an embryological study would be necessary to straighten it out. It doubtless is a fusion of at least two. Its one large nerve runs mainly to the proleg and on its way serves as a stalk for the nerves of the preceding joint.

COMPARATIVE ANATOMY.

Including this paper I can find only five widely separated families represented by dissections of the muscular system, namely:

COSSIDÆ; *Cossus cossus* by Lyonet.

NOTODONTIDÆ; *Pygæra bucephala* by Lubbock.

LASIOCAMPIDÆ; *Malacosoma americana* and *disstria* in this paper.

NOCTUDIDÆ; Two species, probably of *Noctua* and *Nephelodes*, both trifidæ and a *Phæocyma* (quadrifidæ) in this paper.

SPHINGIDÆ; *Delilephila lineata*, briefly by Berlese; and *Sphecodina abbotii* in this paper.

These few species indicate, however, that the characters of the muscles are likely to be as well marked as of any other part; the following points stand out most strikingly:

In the *Sphingidæ* the muscles, especially the large ones, tend to be broken up secondarily into a considerable number of fibres. This shows strikingly in the recti. Q and R show a variety of lengths and tend to run to at least two secondary annulets; x and p cross the middle line and interlace with each other. Well marked resemblances to Cossus appear in the broad convergent and overlapping e and ff, in the filling of the body cavity with tracheæ, and the slight differentiation of 4. The thoracic muscles are particularly massive; the longitudinal connectives are fused unusually far in the thorax, and completely in the abdomen, throwing the apparent origin of the sympathetic fibres back to the ganglion of the next segment.

The *Cossidæ* show their primitive character in the well separated ganglia in the seventh segment, the slight differentiation of 4, the fact that x is nearly longitudinal and hardly distinct from t, even in the segments with prolegs, and the well developed ninth segment of the abdomen.

The *Lasiocampidæ*, like the Sphingidæ, show a tendency to increase of muscles, but it is slight. The deeper transverse fibres alone become numerous and unstable; they are weak and altogether much as one would expect in a form which had passed through a lappet-bearing stage and was degenerating. It is not unlikely that such a larva as Epicnaptera will show a strong and highly specialized lateral system. The differences between the two species is slight, in the first segment *disstria* has only three, *americana* usually five ventral rectus muscles; the lappets are much distincter in *disstria*, but not really functional, so that the difference is not noticeably reflected in the muscles. As a whole the genus is characterized by the massive upper fibre of ζ, a suggestive character in a lappet-bearing family, and the frequent presence of the aberrant fibre f' (as figured) in both species. In the eighth segment there is a large tracheal tuft, which may serve as a sort of lung to aerate the blood where it first enters the heart.

The *Noctuidæ* are marked by their simple and normal condition, without the primitive points of Cossus or the specializations of the others, and are closely similar to each other. p and x meet on the middle line, but do not cross, as in Cossus. In general they are much like Cossus, but possess 4, and p'. The tracheæ are reduced and inconspicuous. Of the two species the Noctua had slenderer lighter muscles. The insertion of p along the midventral line is a little different in character, and as it leaves its trace on the skin may prove a help in identifying in this difficult group.

A Catocaline caterpillar, apparently a *Phæocyma*, shows a number of interesting specializations, apparently connected with its extraordinary jumping power. The thorax (Plates XVII and XVIII) is normal in general plan, but with various oblique muscles joined end for end into long sets; four pair of these, namely, E. α_1, α_2, and α_3; C^+, L and G; α, C, S and L; and c, f and C extend the whole length of the thorax and there are several other shorter sets, while only the α system of the meso- and metathorax was recognized by Lyonet in *Cossus*. The peculiar breaking up of S in the metathorax at least, caused apparently by the attachment of I through it, does not even occur in other Noctuids, about the mesothorax I am uncertain, as that part of my specimen was damaged in dissection. The principal peculiarities of the abdomen, aside from those resulting directly from the slender body, are the setension of F to the acrosternite, under α and ζ, the extension of d well into the following segment outside the other ventral muscles and the simplified leg-muscles of A3, correlated with the much reduced proleg; the most noticeable point in this is that while not forming a longitudinal series of transverse fibres as they do in the seventh segment, muscles m and q are represented by a series of several evidently homologous fibres. The nervous system also shows the highest specialization I have seen in a caterpillar; as the first abdominal ganglion is moved forward well into the thorax (Pl. 1, Fig. 1) and the fused last ganglia have also moved forward into the preceding segment and nearly fused with the sixth abdominal. Their nerves, however, are normal, except for the oblique direction.

Lubbock has notes on a few other species in his paper, among them a Pieris.

SUMMARY.

1. Corrosive sublimate produces the most perfect material for dissection of the muscles; four per cent. formalin is more generally satisfactory.
2. The caterpillars should be opened out before hardening.
3. Lyonet's work has proved fully satisfactory, and Lubbock's sufficiently so for almost perfect correlation of the two.
4. The meso- and metathorax are alike, the first eight segments of the abdomen much alike, and capable of general correlation with the thorax.
5. The ninth abdominal segment is much reduced, but an unquestionable segment. It is less reduced in the most generalized form.
6. The first and last segments are of a different type, and probably compound in nature.
7. The first spiracle has moved forward, the second has become rudimentary in situ and the other eight have moved back, but the first rather less than the others. All have the same innervation, in the abdomen largely from the preceding segment.
8. The meso- and metathorax alone have muscles traversing the nerve-cord.

9. The anterior nerve trunk divides the longitudinal muscles into superficial and deep sets, and the longitudinal trachea similarly divides the transverse ones.

10. The antecosta and ventral precosta arise as specializations of the acrosternal insertions of the muscles and exist only in specialized segments. The muscles may exist in their absence.

11. Characteristics are pointed out of members of five families and characteristic figures are published of a Noctuid, a Lasiocampid and a Sphingid.

12. The following muscles are differently lettered by Lyonet in the meso- and metathorax.

MESOTHORAX	METATHORAX	MESOTHORAX	METATHORAX
G, H	H only	m	3d belly of α
1st belly of α	G	γ	2nd belly of α
e, f	e only	ϵ	γ
d	f	ζ, φ	ϵ, ζ, φ

It is suggested that his lettering of the metathorax be adopted in general, but that m be used for the posterior of the three muscles he confused as α.

13. The muscle marked E by Lyonet, and IX by Berlese is only a segment in length, both terminations being on the antecosta.

14. Cases occur of wide shifts in the origin and insertion of muscles, both relative and absolute, notably in the primitively longitudinal ones p, p', and x, near the midventral line and in d and F of Phaeocyma; they should therefore be used with a good deal of caution in identifying sclerites or parts of the body, at least where as in the caterpillars the sclerites are obsolescent.

BIBLIOGRAPHY.

The following items refer to the Lepidopterous larvæ, Bibliography of the other insects may be found in Berlese, l. c. I, 460.

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A complete monograph of caterpillar structure based on *Cossus cossus*, (family *Cossidæ*) with numerous engraved plates, illustrating, among other things, the entire muscular system and its nerve-supply.

LUBBOCK, J.: Arrangement of cutaneous muscles of the larvæ of ***Pygaera bucephala***. London, 1858.

Family Notodontidæ.

BERLESE, ANTONIO: Gli Insetti; Milano, 1909.

A long chapter on insect muscles and their homologies, with figures of ***Deilephila*** (***Sphingidæ***) and numerous non-Lepidopterous insects.

EXPLANATION OF FIGURES.

Plates XVII and XVIII—Dissection of the thoracic muscles of *Phaeocyma* sp., following Lyonet's lettering, and nearly following his order of dissection. The muscles not hatched, which appear in the various layers are those which appear more distinctly in succeeding ones. The dorsum of the mesothorax, and the prothorax, especially in front are incomplete.

oes. suboesophageal ganglion.
gang. T^1. First thoracic ganglion.
gang. T^2. Second thoracic ganglion.
gang. A^1. First abdominal ganglion. The ganglion of the metathorax lies near the letter c of that segment, under the muscles c.
tr. Functional trunk-trachea of the thorax.
sp. A^1. First abdominal spiracle.
D, A, B and E at the lower edge of Fig. 1, and E on Fig. 2, belong to abdominal muscles, the latter extending forward well into the thorax.
Rudimentary crossed muscles are shown in Fig. 1, overlying the prothoracic ganglion.
In Fig. 6 the stippled areas represent the position of the wings; they underlie all the muscles except the long fibres of T and w.
sp. in Fig. 6 is the rudimentary second thoracic spiracle, in Figs. 4 and 5 π indicates its trachea.

In this and most of the other figures the musculature is shown as it appears when the caterpillar is opened and spread out, the muscles nearest the body cavity appearing superficial, and the last layer of dissection representing the ones close to the skin. In this figure the head was cut in several pieces to enable the prothorax to be spread out flat, and the broken lines represent the mid-dorsal and midventral lines, marked by the position of the dorsal vessel and nerve cord. The small muscles of the legs are not shown.

Plate XIX.—Metathorax of *Noctua baja* (?), dissected in six stages, following approximately Lyonet's directions and using his lettering.

gang. Ganglion.
sy. Fork of sympathetic nerve.
π. Rudiment of middle thoracic spiracle and its trachea.
im. Rudiment of an imaginal muscle.
The wing is shown in the deepest dissection and coarsely dotted.

Plate XX—The middle abdominal segments of *Nephelodes minians* (?) similarly dissected in six stages, in the following order:

1, 2,
4, 3,
5, 6.

Plate XXI—Middle segments of *Sphecodina abbotii*, dissected in the same order, in four layers.

tr. Trachea.

Plate XXII—Middle segments of *Malacosoma americana* dissected in four layers in the following order:

2, 1,
3, 4.

d. v. Dorsal vessel or heart.
w. h. wings of the heart.
sp. Spiracle.
tr. trachea.
gang. Ganglion.
sy. Fork of sympathetic nerve (belonging to preceding segment).
The position of the hooks of the proleg is indicated by a series of bars.
5 is a small muscle in the planta.

Plate XXIII—First two layers of muscles of the first two segments of the abdomen of *Malacosoma americana,* the first layer on the right.

In all the preceding dissections the caterpillar is represented as if opened on the dorsal line and spread out flat, so that the mid-dorsum is divided between the two edges and the midventral line lies in the middle.

Plate XXIV—Ventral musclature of the posterior segments of *Sphecodina abbotii.* The left side is shown as seen from the inner side. 1, as seen when opened and spread out; 2, after removing the muscles hatched in Fig. 1; and 3, similarly after removing those hatched in Fig. 2. The principal nerves are shown as wavy black lines; the segments are numbered and their boundaries indicated in Fig. 1 by arrows.

Plate XXV—Diagrams of segment.

Fig. 1. An abdominal segment (left half) spread out and with the principal annulets and regions labelled, modified after Berlese.
ACRO. acrotergite.
PRO. protergite.
MESO. mesotergite.
META. metatergite.
The four sternites are similarly placed.
sp. spiracle.
ap. tergostern. tergosternal apodeme, pleurosternal suture, or subventral fold.
ante. antecosta (ventral end).
pre. precosta.
inter- intercosta.
pl. planta of proleg.
φ, ψ. Minor apodemes.
ω. ringlike folds, considered by Berlese to mark rudimentary segments of the leg.

Fig. 2. A similar diagram of the metathorax, as developed, e. g. in Sphecodina.
w. Wing-bud, marking the upper boundary of the pleurites.
pleur. pleurite, its boundaries indicated by arrowheads.
m. cx. membranous part of coxa.
ch. cx. chitinized part of coxa.
ACRO, PRO, MESO. and META., as in Fig. 1.

Fig. 3. A superposition diagram of the muscles of the metathorax as seen from within. Each muscle is represented by a double line, interrupted where it passes under another, and the insertions are shown as heavy black bars or dots. The diagram is meant to show the relative position, insertion and direction of action of the muscles, but not their size or form, and is supplementary to Pl. XIX. The rudimentary spiracle and trachea is indicated to the right of the letter θ. Middorsum at left edge, mid-venter at right. c and k, which cross far beyond the middle line, are only partly shown.

Fig. 4. A similar diagram of a middle abdominal segment, serving as an index to Plates 4-6. Dorsally the precosta and intercosta are shown, laterally the antecosta, and ventrally the precosta, pleurosternal suture, apodeme φ (running to the left of the letter ζ) and the oval indicating the boundary of the proleg. The ganglion is dotted, and the anterior nerve indicated as a waved line.